Energetic Particles and Magnetic Fields in the Earth's Magnetosphere and Interplanetary Space

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OBJECTIVES

To advance observational knowledge and understanding of

1. the propagation of energetic particles in the interplanetary medium,

2. the dependence of the intensity of galactic cosmic rays on solar activity and on distance from the Sun,

3. the perturbation of the Earth's inner radiation belt by geomagnetic storms, and

4. the nature of Jupiter's inner radiation belt.

REPORT OF PROGRESS

Objective 1(a)

The following paper has been submitted to and accepted by the Journal of Geophysical Research-Space Physics. It is now in press. The title page and abstract are as follows:

Mean free paths of solar electrons ($E_e > 45$ keV) in the interplanetary medium

Abstract. This paper reports intensity-time signatures of eight impulsive (nearly) pure solar electron ($E_e > 45$ keV) events observed in interplanetary space in the heliocentric radial range $0.7 < r < 1.0$ AU, seven by Mariner V (July-October 1967) and one by Mariner II (November 1962). In six cases, simultaneous solar X ray and Earth-based optical data provide reasonably certain identification of the causative flares. Complementary data on X ray emission and electron angular distributions from Explorer 33 (in a loose Earth orbit) and Explorer 35 (in a lunar orbit) are also cited. In all eight cases the electron signatures exhibit a two-phase structure, an early scatter-free peak [Lin, 1970] having a duration of < 20 min and a subsequent main phase having a full width at half maximum of several hours. A detailed analysis of each intensity-time signature is described, and the corresponding parameters are tabulated. All main phases are well represented by a three-dimensional, isotropic diffusion equation, although it is puzzling that such a representation can be so empirically successful. The principal results are apparent values of the interplanetary diffusion coefficient D and corresponding values of the mean free path lambda between scattering centers for the main phases. Values of lambda range from 0.035 to 0.154 AU. The mean of these values is 0.091 (plus/minus 0.013) AU and the standard deviation of individual values from the mean is 0.040 AU. This standard

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deviation exceeds the estimated uncertainty of each determination by a factor of about three and is plausibly attributed to variability of the properties of the interplanetary magnetic field.

(Primary support by ONR)

Objective 1(b)

The University of Iowa's cosmic ray instrument on the Ames Research Center/NASA spacecraft (now beyond 71 AU) Pioneer 10 continues to yield reliable data. Analysis of the data is supported in part by ONR. See: Eos, Transactions, American Geophysical Union, Vol. 79, No. 10, March 10, 1998, Page 123

Update on Pioneer 10

About a year ago the National Aeronautics and Space Administration announced the formal termination of the extended mission of Pioneer 10 as of March 31, 1997. On March 3, 1997, the 25th anniversary of the launching of Pioneer 10 was celebrated in Washington, DC at NASA Headquarters and at the National Air and Space Museum. I was among those who gave eulogies for the truly pioneering achievements of this Ames Research Center spacecraft to Jupiter and the outer heliosphere.

The services of the outside contractor for Pioneer 10 operations at the Ames Research Center were, in fact, terminated on March 31, 1997. But, by virtue of informal support by the Deep Space Network and the Ames Research Center, Pioneer 10 has continued to yield valuable data on cosmic-ray intensity in the outer heliosphere throughout 1997 and is expected to do so through at least early summer of 1998. The r.f. telemetry link margin, at 16 bits per second, is still satisfactory and the on-board electrical power from the four radioisotope thermoelectric generators (RTGs) is adequate to operate all essential spacecraft systems plus the University of Iowa's cosmic-ray instrument. A precession maneuver to adjust the pointing of the axis of the spacecraft's parabolic antenna was successfully executed on February 3, 1998.

A special scientific objective during 1998 is to learn whether the cosmic-ray intensity starts to diminish from its 1997 maximum as solar activity increases, or whether it increases further to signal approach to the modulation boundary of the heliosphere in the antapex direction.

Until February 17, 1998, the heliocentric radial distance of Pioneer 10 has been greater than that of any other manmade object. But late on that date Voyager 1's heliocentric radial distance, in the approximate apex direction, equaled that of Pioneer 10 at 69.419 AU. Thereafter, Voyager 1's distance will exceed that of Pioneer 10 at the approximate rate of 1.016 AU per year.--J.A. Van Allen, University of Iowa, Iowa City, USA

Objective 1(c)

At the present time I am conducting a retrospective study of a special feature of our original Explorer I data, namely the perturbation of the Earth's inner radiation belt by the geomagnetic storms of 11-13 February 1958 and 10-13 March 1958. These previously unpublished effects are, of course, the first in situ observations of such effects in space and still have unique value. The analysis is well along toward completion. The planned paper is tentatively entitled: "Dynamics of the Earth's Inner Radiation Belt: Explorer I Revisited"

(Primary support by ONR)

Objective 1(d)

An Iowa colleague has recently published the following paper on the inner magnetic field of Jupiter.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 103, NO. A8, PAGES 17,535-17,542, AUGUST 1, 1998

An Improved magnetic field model for Jupiter's inner magnetosphere using a microsignature of Amalthea

Bruce A. Randall Department of Physics and Astronomy, University of Iowa, Iowa City

Abstract. Observation of a particle absorption microsignature of the Jovian satellite Amalthea during the Pioneer 11 close flyby of Jupiter on December 3, 1974, has been described by McKibben et al. [1983]. The microsignature was also observed by the University of Iowa/Pioneer 11 instrument in the distribution of protons in the kinetic energy range $0.61 < T_p < 3.41$ MeV but has not been previously reported. The finer time resolution and superior data quality of the latter observations provide a fresh basis for assessing the accuracy with which various published models of Jupiter's magnetic field

describe the field for radial distances of the order of or less than several planetary radii. The expected time of occurrence of the minimum of Amalthea's microsignature was calculated for each model and compared to the time of the observed minimum. The discrepancy between these two times was significant for each of the published models, but it could be reduced to zero by interpolating between two of the closely related models. The spherical harmonic coefficients of this combination model are tabulated. Also included is a novel method for calculating the intensity-time profile of the microsignature. In a later paper, the improved model is utilized to analyze the energetic particle measurements in Jupiter's innermost magnetosphere by the Galileo entry probe in December 1995 [Fischer et al., 1996].

(Partial support by ONR)

Randall and I are now working on analysis of our 1973 Pioneer 10 and 1974 Pioneer 11 observations of the inner radiation belt of Jupiter and their relationship to those of the 1995 Galileo entry probe. Matters of particular interest are the absorption of energetic particles by the innermost satellites and rings of Jupiter and the possibility that a new ring of particulate matter was created by the impact of Comet Shoemaker-Levy in 1994.

(Partial support by ONR)

PROGRAMMATIC NOTE

At our request ONR has recently granted a no-cost extension of our subject grant to 31 December 1999 in order that we can complete and publish ongoing work.